

Title: ULLAGE METER FOR A TANK OF COMPRESSED GAS AT ELEVATED  
TEMPERATURE

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CROSS REFERENCE TO RELATED APPLICATIONS

Paron, et al. US 5,738,442

Santacaterina, et al. US 4,779,995

STATEMENT REGARDING FEDERAL SPONSORSHIP - n.a.

10 REFERENCE TO A MICROFICHE APPENDIX - n.a.

BACKGROUND OF THE INVENTION

15 The available dive time for a SCUBA diver is a function of his compressed air supply. A freshly pressured tank usually has elevated temperature due to the heat generated by the compressor, if one is used, or due to the heat picked up as gas expands out of a high pressure storage tank and compresses into the SCUBA tank. As a warm, filled tank equilibrates with cooler ambient air or water, the pressure drops. This amounts to an ullage in the freshly filled tank. This ullage represents a concomitant loss in available dive time compared to that of the same tank filled to capacity with temperature-equilibrated air.

20 Divers use their compressed air tank pressure to predict how long they can stay down. Normally, a diver desires a maximum dive time - a maximum pressure at the start of a program of diving. Also, at the time a tank is filled, the diver would like to know how much air he actually will have after the tank temperature finally equilibrates. A tank filled to capacity with warm air will have less useful air than might be indicated by full pressure before the tank cools off.

25 Any prediction of ullage for a freshly filled tank must be based on a temperature measurement of the freshly filled tank. Santacaterina (US 4,779,995) has invented a system of color temperature strips. His patent lists sixteen other related patents. Paron (US 5,738,442) has invented a temperature indicator for a wine bottle based on art similar to that of Santacaterina. Neither pressure nor ullage is related to these patents. Yet, these patents use the kind of temperature sensitive material that might be used in the present concept. The material changes color at a particular temperature depending upon the design of its makeup.

30 Teletemp company of Fullerton, California makes one type of temperature indicator which can be used in the present invention. Liquid crystals are formulated for a specific temperature

response. In the response reflected light is modified to allow a message such as a specific pressure to be seen. Unless the temperature is within the designed range of the liquid crystal material, the indication is black. The adhesive-backed liquid crystals have been used to indicate body temperature, as refrigerator thermometers and as hot warning labels to name a few.

## 5 BRIEF SUMMARY OF THE INVENTION

Sub E1  
10 Gas storage tank cooling after filling and the prediction of the future air supply from a cooling tank has been a problem without solution for divers in spite of the great expansion of SCUBA sport over the past forty years. The diver has no real use for the tank temperature. What he really needs is an indication of what the supply of air will be from the warm tank supply after the tank has cooled. The diver knows his tank and its capacity in terms of minutes of diving - if it is completely filled at the start of a dive with temperature-equilibrated air. The purpose of this invention is to tell the diver what percentage ullage his fully pressured tank has as he leaves the fill station. With this invention indicators on the tank surface that are actuated by the tank wall temperature do this. Change in color due to a particular temperature allows a particular ullage number to be seen. The ullage number is pre-calculated based on the gas law of temperature effect on pressure at constant volume. Each ullage number is based on one hypothetical final gas temperature or a variety of patches can be used, each not only based on a given temperature immediately after filling, but also each based on an expected cooled, final temperature.

## 15 BRIEF DESCRIPTION OF THE DRAWINGS

20 Figure 1 is a general case of an ullage meter showing a printed label for a gas storage tank with an assortment of ullage indicators each dependent upon a (1) different combinations of pressure and temperature after fill and (2) an equilibrium temperature to which the tank will have cooled some time after fill

25 Figure 2 is one example of a specific set of conditions for the design of Figure 1, the tank ullage meter being observed right after the fill.

## DETAILED DESCRIPTION OF THE INVENTION

30 In Figure 1 can be seen a coating 1, either painted on the tank or attached as a paper-thin film, for a pressurized gas tank. The coating is in the form of a table of conditions for a pressure tank holding gas. In detail the coating 1 is made up of an assortment of distinct areas in columns 2, 3 and 4 wherein the background of each column is made up of a different material, each sensitive to a different temperature. While any variety and range of activation temperatures is possible within a design of coating, in this representative case each of the columns 2, 3, and 4 are cross hatched

5 differently to represent, within each column, materials of the same temperature sensitivity within a column and with different materials in each column. When the specific activation temperature (TF1 or TF2 or TF3) of a given column is reached, the material changes color so as to illuminate the numbers for the column. The change can be from black to a lighter shade which allows the numbers to be seen or it might be from a particular color to a colorless, clear presentation. The change in color might persist over a relatively small range of temperature or it might persist at any temperature above a certain level. The nature of the numbers showing after activation is noted, as pressure (psi) or percent of original pressure, on each of the squares of the three columns. Columns 5 and 6 have fixed, visible numbers defining the associated final equilibrium temperatures and initial pressures upon filling.

Imprinted within the coating 1 in the second column from the left, 5, are, for example, two different equilibrium temperatures, one to be selected by the reader of the coating to represent the expected final, equilibrium temperature of the filled gas tank. Column 6 specifies for rows 7, 8, 9, and 10 the tank pressure immediately after fill is complete. The numbers of columns 5 and 6 are always visible. Rows 11 and 12 have no pressure after fill and they indicate, upon the temperature activation, the percentage drop to be expected in whatever the final fill pressure is, the drop being fully realized as the warm, filled tank reaches the lower equilibrium temperature.

In the example of Figure 1 the temperature sensitive material of all of the areas in the column 2 react at the same temperature. The column 3 and the column 4 areas have two other distinct temperatures of activation.

The numbers for each of the many areas of columns 2, 3, and 4 are calculated using the classic gas law with inputs of absolute temperatures (both temperature after fill, TF1 and equilibrium temperature, TE) and absolute pressure and output of pressure as psi or percent, volume being constant in all cases. In the cases of rows 11 and 12, one minus the ratio of equilibrium temperature, degrees absolute, to the temperature after fill, degrees absolute, gives the fractional drop in fill pressure to be expected. While the temperature after fill is the basic activator to highlight the "pressure drop" or the "percentage drop" in a particular row, the temperatures are not the key information, it is the pressure effect and this is literally spelled out in a particular area either as psi drop or percentage drop in pressure.

In summary, Figure 1 shows a table to be imprinted upon a gas container to show for various initial pressures (or for any initial fill pressure in the last two rows) and final, equilibrium

temperatures, the pressure loss from the initial filled pressure for three cases of tank temperature at the time the filling is complete.

Sub 5  
F2  
This concept can be expanded beyond the example of Figure 1. Any number of columns in addition to 2, 3, and 4 for different temperatures can be used; any variety of combinations of pressure and temperature immediately after fill and of final equilibrium temperature can be used. In some cases for the temperature sensitive indicator a particular activation temperature might not be available. Then, the nearest one would be used and the proper psi drop or percentage drop would be calculated and imprinted on the given area.

10 Figure 2 illustrates the case of Figure 1 where the tank has a temperature of 110 degrees F. or higher. The numbers for 110 degrees have become visible, as have those for 95 degrees. To define the temperature more precisely there would have to be additional columns to register for temperatures between 110 degrees and 120 degrees.

15 The invention is not limited to the particular cases seen in the figures. In general, the use of temperature sensitive materials applied to the surface of a gas storage tank to indicate the effect of cooling of the tank on the pressure would be covered by this invention.